APPENDIX

South Platte Implementation Background

This document presents preliminary information about the South Platte basin for use in the development of an implementation plan for streamflow regulation accounting in forecast operations. It is formatted along the lines of the implementation approach outlined in a memo dated 26 March 2004 on the subject of general streamflow regulation modeling strategies. Information is presented only for the *Basin Inventory* and the *Data Analysis and Synthesis* sections of the implementation approach.

Basin Inventory

Objective

Collect as much information as possible in order to adequately understand the regulation in the river basin. The primary questions that need to be answered at this stage are 1) WHAT types of regulations are affecting the river, 2) WHERE are these regulations occurring, 3) WHO is responsible for the regulations, and 4) WHY do they operate as they do. This information provides the basis for making qualitative assessments of the relative streamflow impacts caused by the various regulation issues.

Steps

Basin Overview: Briefly describe the basin characteristics, major water uses, and other important facts.

The South Platte River basin has a drainage area of over 23,000 square miles, covering lands in Colorado, Wyoming, and Nebraska. Most of the flows originate from the melting winter snow pack, thus producing large spring and early summer runoff. The USGS has estimated the annual native flows for the basin to be 1,400,000 acre-feet. Trans-basin water provides another 400,000 acre-feet, primarily from the Colorado River. Groundwater pumping from high capacity alluvial wells located along the South Platte is estimated to provide approximately 640,000 acre-feet per year. There are about 1,800,000 acre-feet of reservoir storage capacity in the basin. Total annual surface water diversions equal approximately 4,000,000 acre-feet. Consumptive use of river water for human purposes (municipal, industrial, irrigation, etc.) is estimated to be around 1,500,000 acre-feet. Overall, the South Platte River system is over appropriated and highly regulated due to large demand levels placed on the limited water supply. Water is used and reused on average three times before it reaches the confluence with the North Platte.

Regulation Identification: Identify both regulation types and regulating entities within the forecast area.

- Identify Types of Regulation: Regulation can occur in many shapes and forms. Most often regulation is associated with a physical structure such as a dam or diversion canal, but can also occur as a result of administrative rules and policy.

The majority of reservoirs and diversion structures in the South Platte basin are used for delivering water to irrigated lands. Municipal water providers continue to acquire additional water supplies (transfers from ag use), including trans-basin imports, as the urban population grows. There are several thousand wells used to pump alluvial groundwater, especially along the lower Platte. Only a limited number of large flood control structures exist in the basin as most reservoirs are used primarily for water supply protection and are located off-channel. In Colorado, the State Engineers Office (SEO) applies the Prior Appropriation Doctrine (first in time ~ first in right) to direct water allocation. Generally, water rights are most senior in the upper tributary basins, while the water rights on the lower mainstem are more junior. Water rights are distinguished as direct flow rights, which require the immediate use of water for

beneficial use, and storage rights, which allow water to be stored for an indefinite period. The South Platte River Compact designates the level of allowable diversions on the lower end of the river in the State of Colorado at times when Nebraska water users have unmet demand on the river. The largest diverter in Nebraska is the South Platte Supply Canal, which diverts large volumes for a hydropower facility. In Wyoming there appears to be very little regulation occurring on the small tributaries to the South Platte.

- Identify Regulators: Regulators can be both the entity owning/operating a regulation structure as well as an agency responsible for enforcing/administering river flows

Regulators in the South Platte basin consist primarily of agricultural irrigators and municipal water providers. Irrigation accounts for 68% of water use, 22% for municipal use, and 3% for industrial. The remaining 7% is used for augmentation and groundwater recharge.

Although many water rights serving agricultural land are still owned by individuals, these private water rights are often combined under one large structure as a mutual ditch. Therefore, numerous water rights can exist at a single diversion point on the river. There are approximately 625 irrigation diversion structures on the South Platte and tributaries. On average, about 50% of the water diverted for irrigation is consumptively used. The remaining water returns back to the river system or recharges alluvial aquifers. Irrigation practices tend to significantly alter the natural hydrograph by reducing spring and summer flows (diversions) and increasing the winter flows (returns).

Of the municipal water providers, Denver Water is the dominant entity, controlling large amounts of native and trans-basin water supplies. Other water providers with significant control of water supplies include the cities of Thornton, Aurora, Boulder, Fort Collins, and Greeley. Regional water districts, commonly referred to as rural domestics, serve many of the smaller towns. There are approximately 700,000 acre-feet of foothills/mountain reservoir storage controlled by municipalities. There is additional reservoir storage on the west slope (Colorado River Basin) that can provide water to the South Platte basin. Most municipal water providers retain, or carryover, stored water during average and wet years so as to be available during drought periods.

There are federally owned and operated regulation structures in the South Platte basin, but they do not play a significant role in terms of overall impact on basin streamflows. The one exception is the Bureau's Colorado – Big Thompson project that imports up to 300,000 acre-feet from the Colorado River to the South Platte. There are three Federal flood control structures on the South Platte; Cherry Creek, Chatfield, and Bear Creek reservoirs.

The SEO oversees the actual allocation of water from the river system and is responsible for enforcing the principles of the prior appropriation doctrine. The South Platte basin is divided into 14 separate administrative districts. Each district has a water commissioner who manages the flow levels at diversion structures. The commissioner considers such things as the estimated natural flow levels, return flows throughout the river reach, downstream calls, reservoir deliveries, augmentation requirements, and other types of restrictions, etc. when determining the legally available diversion rates. It should be noted that the alluvial wells are administered similar to surface water rights, and that during low flow periods, groundwater pumping may be restricted. A direct flow water right has a date of appropriation and an upper diversion rate. Rarely are volumetric limitations placed on a direct flow right, so long as the water is being placed to a beneficial use. Although many states require a minimum "bypass" flow at diversion structures, water users in Colorado are generally allowed to divert the entire flow of the river if it is within their water right. The earliest adjudicated water rights date back to the 1850's. In the South Platte, a water right dated 1880 or later is considered a mid-junior water right and may not yield water during dry seasons. Many junior water rights only yield water during the peak runoff periods. Storage water rights

have a date of appropriation as well as an annual volume restriction that is usually based upon the physical capacity of the storage reservoir. Storage rights generally do not have a maximum diversion rate restriction. The SEO operates on a November – October water year, different from the USGS October – September water year.

- Establish Contacts with Major Regulating Entities: After identifying regulators, contacts within the regulating entity must be established in order to gain access to data and information.

Much of the diversion data will be available via a third party (state or federal administrative agency), but the actual operating and decision-making process may not be readily available and must be requested from the particular entity. Sometimes formal channels must be used, while other entities can be approached in a more informal manner. As a result of previous and on-going engineering projects, RTi has developed contacts within the SEO and several local governments. We also contacted and received information from Denver Water, Boulder Public Works Department, and City of Fort Collins Water Utility.

This item highlights the importance of a local presence. Gaining access to information and knowledge takes time and relationships must be developed, especially with private entities.

Information Collection: Several different types of information are required to fully describe streamflow regulation

- Data: Time series observations including streamflow, diversions, reservoir levels and releases, and other hydrologic features are usually collected and maintained by a government agency.

For the South Platte, historic diversion and reservoir data is publicly available through the SEO's hydrobase database system. The quality of data is generally quite good for post 1970 observations. Earlier data is somewhat suspect and may need qa/qc. Most of the data is available on a daily time step, although inspection of data suggests that quite often daily flows were derived from weekly or monthly observations. Storage contents for reservoirs are often available only on a monthly increment. Daily streamflow data is available through both USGS and SEO sources.

Data corresponding to system operations beyond the original diversion structure are usually not publicly available. For example, the SEO will record flows off of the river, but does not track the final delivery point. This level of information may be maintained by the entity diverting and using the water, but often times it is difficult to access this information. Many smaller organizations (ditch companies) still keep records in hard copy format.

The main challenges in this step are overcoming the problems posed by varying levels of data quality, different formats, and various time-steps for data reporting.

- Basin Administration: Administrative records provide an overview of the past water years and typically highlight any type of exceptional operational action.

Information recording the administration of the river may be available through river "call records". These records are helpful in understanding which water rights were in priority throughout the course of the water year. In addition, other types of administrative records such as river exchanges, augmentation releases, groundwater pumping restrictions, and compact deliveries provide important information describing the operations in the river. Interviews with administrative officials such as division engineers

and district water commissioners is recommended, as these personnel can provide simple "rules of thumb" that succinctly define how their particular river reach is managed. For example, the record drought of 2003 forced the curtailment of groundwater pumping throughout the South Platte basin. This extreme administrative action had never before occurred.

- Operational Information: Published operational reports, such as annual operating reports for Bureau Projects, provide the basis for developing operational rule curves. Many private regulating entities do not publish reports making data acquisition more difficult.

The larger regulators may publish periodical Annual Operating Reports that provide insight into their operations. This type of information should be available for all government-operated projects. The Bureau publishes an annual AOP for the Colorado – Big Thompson project. Its purpose is to inform interested parties of the coordinated operation of the project. It contains a summary of operations as well several tables containing observed flows and reservoir levels. Obtaining this type information from private entities, especially those involved in power production, is more difficult.

Often, information concerning both basin administration and operation will be anecdotal in nature. Many arrangements exist between water users, such as water exchanges, that are informal and undocumented. Although these arrangements are indeed a form of streamflow regulation, they do not appear in any type of official database and would not be revealed by analyzing historic diversion records. These types of operational arrangements and agreements exist throughout most basins and can pose major difficulties when trying to draw objective conclusions based upon time-series data analysis.

- Existing Studies and Reports: Hydrologic/Engineering studies are an important resource and can provide a significant amount of insight into the river system

Many of the reports that we have acquired contain detailed hydrologic studies that would not be practical to reproduce within the scope of AHPS. A good example is the calculation of naturalized, or virgin, flows at selected gaged locations throughout the basin. We have naturalized flow data for several sites on the South Platte mainstem, Boulder Creek, the Big Thompson River, and the Cache la Poudre River. These studies were directed by either municipal water providers (looking for additional source of supply) or the state. Most of these studies have been performed on a monthly time step, although some have been developed on a daily time step going back into time close to 30 years. In any case, such reports can be a tremendous time saver when performing quantitative analyses on the NWSRFS segments.

- GIS / Maps: USGS quad maps and GIS data provide the means to identify spatial distribution and location of regulating structures

Many of the larger regulating structures in the South Platte convey water from one segment and deliver it into another. This type of intrabasin water transfer is fairly common in water short areas such as Colorado. Maps and GIS are necessary to track the movement of water throughout the basin.

High Level Basin / Segment Characterization: Before in-depth analysis begins, the basin should be evaluated and characterized to identify strategic issues

- Characterize Segments: Characterize in terms of general hydrology, operations, and administration

The South Platte basin has an obvious delineation between the upper (mountains and foothills) and lower (plains) portions of the basin. The upper basin is characterized by many storage reservoirs, interbasin and transbasin conveyance structures, and more senior water rights. The water rights and storage vessels located in the upper basin are predominately owned and controlled by municipal water providers. The

main reasons are good water quality and good reservoir sites. On the other hand, the lower basin is generally controlled by agricultural interests and is characterized by numerous diversion structures, extensive canal delivery systems, and off-river storage reservoirs that serve as both a source of supply late in the summer and as a regulating mechanism on the canal system. Limited amounts of groundwater pumping occur in the upper portion, while the lower reaches of the South Platte are significantly affected by pumping. Water quality in the lower South Platte is too poor of quality to be economically treated for potable use.

- Identify Key Regulation Points and Practices: Major regulations/regulators that have the capacity to affect multiple segments must be identified

After a cursory review of the available information, it should be possible to identify the major regulators, regulation points, and possibly even the hydrologic triggers that drive operational decisions. For the South Platte basin, we are able to recognize the importance of reservoir operations and transbasin deliveries as a function of Denver Water's and other municipal water providers' operations, as well as the fact that these particular regulations may need to be represented explicitly in the NWSRFS model. On the other hand, the sheer number of agriculture diversions in the lower basins makes it clear that we must consider some type of aggregation method in order to represent these regulations. Other regulating relationships and issues will only be adequately understood after the quantitative segment-by-segment analysis.

Data Analysis and Synthesis

Objective

Isolate and analyze regulations in each individual segment and then synthesize this information at a system level. The intent is to define the cause and effect relationships between the streamflow and the regulation. Success in this task will be largely determined by the quality of information collected in the earlier stage. The next step is to consider those regulations that transcend the boundary of a single segment and to measure their range of influence, both upstream and downstream. Ultimately, we would like to understand how all of the different regulators/regulations interact and affect one another and how they manage to operate together in a single, comprehensive system.

Ultimately, there are 3 effects of regulation on streamflow: increase flows (imported water), decrease flows (divert and consumptively use), or alter the timing of flows (dams). Many forms of regulation will be responsible for more than one effect.

Steps

Formulate Analysis Tools: Data and information management poses a particular challenge in this stage. The investigator must merge information and data from multiple sources and formats

Each segment has different sorts of issues and data availability, and must be handled in its own manner. It would be very difficult to apply a template approach to analyzing the regulation effects in each segment. The flexibility provided by a spreadsheet environment seems to be appropriate at this level of analysis. We have approached this task by assigning each NWSRFS segment to a worksheet in an Excel Workbook. Time-series data can be arranged and analyzed, schematics can be drawn, and observations can be recorded on a single worksheet. Most of the data that we are working with at this stage is based upon a monthly time-step. Hourly, or even daily data may be overwhelming, but under certain circumstances (e.g., hydropower operations) it may be required to adequately understand regulations.

Control Volume Diagram: Diagrammatic and quantitative segment analysis provides the basis for understanding streamflow regulation.

- Diagram inflows and outflows: Develop a diagram showing inputs and outputs from each segment.

- Segment Mass Balance: This is a basic mass balance approach to identifying the timing and magnitude of the inflows / outflows occurring within each segment.

For the segments in the South Platte, control points are the upstream and downstream gaged streamflows. By comparing long term flows at these two locations (for similar time periods), one can determine whether or not the reach is gaining or losing. The next step is to identify the types of regulation causing the increase or decrease in stream flows and the timing. Headgate diversions, changes in reservoir volumes, and other regulation observations are required. For areas with significant amounts of consumptive water use, such as irrigation districts, it may be necessary to perform some type of irrigation water requirement analysis (e.g., Blaney Criddle analysis) to determine estimates for how much water can be practically removed from the system.

- Naturalized Flows: Naturalized flows can be calculated by adding/subtracting regulating effects at the downstream gage. These results may be helpful for calibration purposes.

Based upon data availability, it may be worthwhile to calculate naturalized flows during the segment analysis step. We have developed naturalized flows along the Poudre River using an existing water allocation model developed for a reservoir sizing project. Naturalized flows at several locations along the South Platte mainstem were developed as part of an SEO study.

Aggregate Regulations: Regulations that have similar operations and effects upon streamflow should be considered as candidates for aggregation.

A good example is a segment that contains numerous diversions for agricultural use. In general, the irrigation systems identified within a single segment will have similar delivery practices and irrigation water requirements. These regulators could be lumped into a single representative ditch. Of the 625 identified agricultural diversion structures, most of these will be aggregated by segment. Only those with unique operations and/or very large diversions will need to be modeled separately.

Classify Regulations by Level of Impact: Regulation can be classified by magnitude, frequency of occurrence, seasonality, and other relevant factors.

Variations in streamflow regulation can be time dependent, location dependent, weather dependent, etc. Some regulations are very constant, while other can have drastic variations. The qualities should be identified and documented. From observation, we can deduce that the storage reservoirs used to supplement irrigation are prone to go completely dry in some years, while reservoirs operated for municipal uses have a much different use pattern.

Identify System Dynamics: Establish a comprehensive overview of regulation effects. Classify local (within segment) and system (spanning several segments) regulation.

An important element to be considered is the hierarchy of operational decision making in the basin. Does one operator trump another? This step requires deductive reasoning and examination, as this type of knowledge will generally not be available in a published report or document. In the South Platte, this hierarchy is well defined by the Prior Appropriation Doctrine and the seniority of water rights. This situation will be completely different in basins managed under Riparian laws.